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Direct Measurement and Evaluation for Mechanical Engineering Programme Outcomes: Impact on Continuous Improvement

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Abstract

Universiti Kebangsaan Malaysia (UKM) is a research university that continuously undergoes an audit and accreditation process for the management of its courses. The Faculty of Engineering and the Built Environment (FKAB) is subjected to such processes, one of them is the auditing conducted by the Engineering Accreditation Council (EAC), which gives recognition to engineering programmes in Malaysia. The criteria that have been set by the EAC requires the faculty to measure and evaluate graduates based directly on the course outcomes (CO) and programme outcomes (POs) to ensure that they are able to achieve the programme and course objectives. This paper discusses a method developed for the measurement and evaluation of POs which is a direct measurement for assessing the courses offered in the mechanical engineering programme. Assessment templates are developed using a Microsoft Excel based on the data presented on the grade coordination meetings conducted at the end of each semester. The data used for this study were semester 2 2010/2011 session, and semester 1 session 2011/2012. Based on the results obtained, the majority of the courses achieves more than 80% for course level monitoring for their individual PO achievement except for five subjects. For programme level monitoring, from the average POs marks, all POs were scored more than 80%, which indicates that the Mechanical Programs offered by the department are satisfied with the department standard.

Keywords: accreditation, EAC, programme outcome

1. Introduction

All programmes in institutes of higher learning and universities are required to implement an outcome-based education curriculum set by the Ministry of Higher Education to ensure quality graduates are produced (Shahrir et al., 2008). The Faculty of Engineering and the Built Environment (FKAB) has initiated the concept of Outcome-Based Education (OBE) in 2005, particularly because the FKAB has to ensure that programmes are recognized by authorized accreditation bodies. The Engineering Accreditation Council (EAC) is one of Malaysia's accreditation bodies and is responsible for ensuring quality engineering programmes at local universities. The EAC has set certain standards to be achieved, emphasizing the measurement of student achievement through the OBE and in a manner that is consistent with the requirements of the ministry (Siti Aminah et al., 2011).

Programme Outcome can be measured by a variety of methods either on questionnaires, grading courses, observation of student achievement, portfolio analysis and interviews. All of these methods can be divided into two approaches, namely the direct or indirect measurement (Breslow, 2007). Allen (2008) explains that the direct measurement methods to assess the students' work in the form of creative assignments and systematically can be assessed based on rubric. While the indirect measurement methods can assess students' perception of learning and teaching environment. The result of this method is often combined with the direct method results. According Wojtczak (2002), Programme Outcome measurement is useful to assess student achievement to meet

the needs of external examiners and also can provide the information for the purpose of improving the curriculum, as well as to document the success or otherwise for a programme.

Based on the OBE approach, the measurement of student achievement upon completion of the course is a requirement to determine the ability of the students based on their cumulative grade point average measurement (CGPA) for each semester. Many of researcher assess the Programme Outcome and Course Outcome based on their student achievement (Ishak et al.,2011, Nurina Anuar et al,.2011, Juridah Johari et al, 2010, Hamimi Fadziati et al,.2010, Mohd Faizal et al, 2012) . OBE also specifies that the assessment results for each course [course outcomes (COs)] will have to depend on what has been stated in the programme handbook. In addition, CO measurement is directly dependent on the achievement of students in each assessment determined in each course as scores from quizzes, tutorials, laboratories, and examinations. Thus, to ensure that the end result is achieved with quality assured, teaching and learning plans should be designed and provided by the course instructor at the beginning of each semester (Rozeha et al., 2007).

Each course offered throughout the mechanical engineering programme has its own COs to be achieved by the students upon course completion. Every course is designed to relate the results and contribute to the achievement of programme outcomes (POs). A detailed syllabus for each course as well as the respective results of the course and its relationship with the PO can be seen in FKAB undergraduate handbook for each academic session. Figure 1 shows the process flow of the presentation and evaluation of student performance and achievement of COs as practiced in the department.

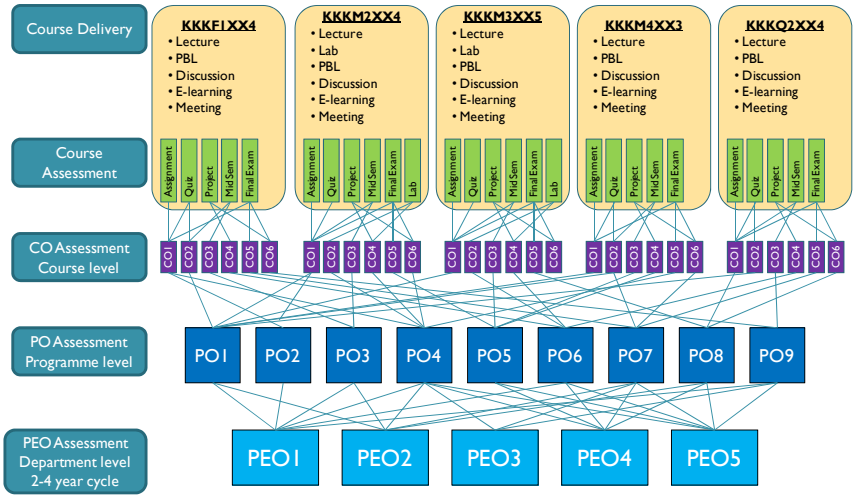


Figure 1. Process of delivery and assessment of student performance and achievement as practiced in the department

Figure 1 shows that every course has specific delivery and evaluation methods for student achievement. Each element of assessment must be performed, and the course instructor must ensure the measurement results of the course evaluation achieve a predetermined threshold at the departmental level (EAC Document JKMB 2012).

Table 1. List of POs of the mechanical engineering and manufacturing engineering programmes

	List of Programme Outcomes
PO1:	Ability to apply knowledge of mathematics, science, and engineering
PO2:	Ability to identify, formulates, solve, and improve engineering problems using techniques, skills, and modern engineering tools necessary for engineering practice
PO3:	Ability to design a component, system, or process to meet desired needs
PO4:	Understanding of professional and ethical responsibility of knowledge of environment and contemporary issues

PO5:	Ability to understand and apply in-depth knowledge of one or more area of specialization in mechanical engineering/manufacturing
PO6:	Ability to design and conduct experiments as well as to analyse and interpret data
PO7:	Ability to communicate and to function effectively in a team
PO8:	Recognition of the need for, and ability to tap into lifelong learning
PO9:	Knowledgeable in project management, administration, business acumen, and entrepreneurship

In the course assessment, each CO contribution to that particular course is mapped to the relevant PO. This enables the evaluation and its contribution toward achieving the PO for the four years of study. Table 1 shows the list of POs for the mechanical engineering programme beginning in semester 2010/2011 (FKAB Undergraduate Handbook 2011).

For each programme, such as the mechanical engineering programme for the second semester of 2010/2011, approximately 20 courses are offered including optional elective subjects. The general role of the programme coordinator is to monitor whether every course offered achieves the COs and PO according to prescribed standards. This paper discusses a template developed to help the coordinator monitor the performance of each subject offered within a semester. The huge number of courses makes it difficult for the programme coordinator to conduct an overall monitoring. However, this template aids in the process of monitoring the expected PO performance of each subject and prevents any course from being overlooked.

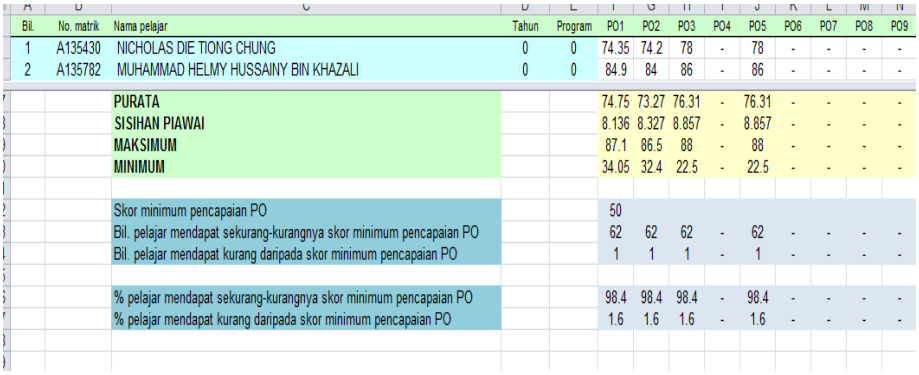
2. Methodology

The measurement procedure was developed using Microsoft Excel format based on the standards established by the department. The template contains the course code column representing the entire departmental programme as well as the percentage fields pertaining to the achievement of outcomes for each course, as shown in Table 2.

Coordinator for each course has to determine his/her CO relationship to POs as stated in the Undergraduate Handbook. They have to define the percentage workload or assessment for every COs towards the particular POs marks. The relationship between POs and COs are static, but the percentage contribution from each COs are varies depending on the instructional planning. Figure 2 shows an example of the weightage for each CO to the PO for subject KM 1914. The correlation between each PO and CO for each course is outlined in the FKAB undergraduate handbook for each semester. For instance, PO3 consist of 50% assessment marks from CO4 and C06 respectively. PO scores were obtained from the scores that have been determined during the grade coordination meetings using scoring templates developed by previous researchers (Shahrir, 2007). Every student's assessment marks such as from examination, tutorial or quiz will contribute to their COs marks depending on the weight distribution between the assessments. Then, the individual POs marks will generate based on the individual COs marks and the weight dissemination between each CO for the particular PO.

PO	Hasil Program	CO1	CO2	CO3	CO4	CO5	CO6	Jumlah
PO1	Berupaya mengaplikasi pengetahuan tentang matematik, sains dan kejuruteraan	15	15	15	15	20	20	100.00
PO2	Berupaya mengenalpasti, memformulasi, menyelesaikan dan meningkatkan masalah kejuruteraan menggunakan teknik-teknik, kemahiran-kemahiran, dan perkakasan kejuruteraan yang mustahak untuk amalan kejuruteraan			30	30		40	100.00
PO3	Berupaya untuk merekabentuk satu komponen, sistem atau proses untuk memenuhi keperluan-keperluan diingini				50		50	100.00
PO4	Pemahaman mengenai tanggungjawab profesional dan beretika daripada ilmu pengetahuan tentang alam sekitar dan isu-isu kontemporari							0.00
PO5	Berupaya untuk memahami dan mengaplikasi pengetahuan mendalam samada satu atau lebih bidang pengkhususan dalam kejuruteraan pembuatan				50		50	100.00

Figure 2. Sample entry weights that determine the relationship between COs and POs



Bil.	No. matrik	Nama pelajar	Tahun	Program	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
1	A135430	NICHOLAS DIE TIONG CHUNG	0	0	74.35	74.2	78	-	78	-	-	-	-
2	A135782	MUHAMMAD HELMY HUSSAINY BIN KHAZALI	0	0	84.9	84	86	-	86	-	-	-	-
		PURATA			74.75	73.27	76.31	-	76.31	-	-	-	-
		SISIHAN PIAWAI			8.136	8.327	8.857	-	8.857	-	-	-	-
		MAKSIMUM			87.1	86.5	88	-	88	-	-	-	-
		MINIMUM			34.05	32.4	22.5	-	22.5	-	-	-	-
		Skor minimum pencapaian PO			50								
		Bil. pelajar mendapat sekurang-kurangnya skor minimum pencapaian PO			62	62	62	-	62	-	-	-	-
		Bil. pelajar mendapat kurang daripada skor minimum pencapaian PO			1	1	1	-	1	-	-	-	-
		% pelajar mendapat sekurang-kurangnya skor minimum pencapaian PO			98.4	98.4	98.4	-	98.4	-	-	-	-
		% pelajar mendapat kurang daripada skor minimum pencapaian PO			1.6	1.6	1.6	-	1.6	-	-	-	-

Figure 3. Final percentages for student achievement of POs for the course KM 1914

For programme monitoring at the individual level, the department has set that every student should get more than 50 marks to be considered archiving that particular PO. Next, from the individual PO marks achieved by each student, the percentage scoring for the PO measurement of each course measure was calculated based on the total percentage of students who achieve at least 50 marks over the total number of students taking the course. Figure 3 shows the final marks achieved by the course at the end of the programme.

The scores for each course will then be transferred to a monitoring template to determine the PO achievement for the whole programme. For programme monitoring at the course level,the department has designated that a PO is achieved if the percentage of students who scored at least 50 marks in a subject is 80%. Any subject that fails to achieve 80% will be marked in yellow, as shown in Table 2, to alert the course lecturer and programme coordinator about the PO-related achievement of the course so that further actions could be taken.

However, to measure the PO for programme monitoring at the programme level, the average of these data, excluding the POs for elective subjects, is calculated. In addition, to obtain a more accurate record, the average PO for selected subjects is also calculated.

3. Results and Discussion

The department offers two programmes: mechanical engineering and manufacturing engineering. To accomplish the self-EAC 2012 report, the department requires an approach for monitoring every course for each semester and for both programmes for 2010/2011 and for semester 1 2011/2012. However, in this paper, only the mechanical engineering programme is discussed with a focus on departmental compulsory courses and faculty, excluding compulsory university courses.

Table 2. Percentage of students who scored a minimum of 50 marks for specific courses for the mechanical engineering programme for semester 2 2010/2011

	PO MARKS								
CODE	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**
KKKM1024	100	100	98.5	-	100	-	-	-	-
KKKF1121	-	-	-	100	-	-	-	-	-
KKKM1324	60.3	-	-	-	-	91.2	-	-	-
KKKM1344	95.7	88.4	-	-	-	-	-	-	-
KKKJ2324	70	90	-	-	70	-	98.33	-	-
KKKJ2344	91.8	96.7	-	-	98.4	95.1	98.4	-	-
KKKJ2724	88.1	90.5	-	-	-	90.5	90.5	-	-
KKKJ3124	73.3	83.3	75.0	-	100.0	71.7	95.0	-	-
KKKJ3164	93.3	95.0	-	-	88.3	90.0	-	100.0	-
KKKJ3344	100	100	-	-	100	100	-	-	-
KKKJ3944	96.7	100.0	100.0	-	75.4	-	98.4	-	-

KKKJ4023	100.0	98.3	98.3	100.0	100.0	100.0	100.0	100.0	-
KKKJ4703	96.6	96.6	-	96.6	96.6	-	96.6	96.6	96.6
KKKJ4543	87.2	82.1	-	-	82.1	87.2	-	-	-
KKKJ4373	93.3	100.0	100.0	-	100.0	-	-	-	-
KKKJ4363	86.7	90.0	86.7	-	-	86.7	-	-	-
KKKJ4513	92	-	92	88	88	92	92	92	88
KKKJ4523	100	100	-	-	-	-	100	-	-
KKKJ4413	-	84.4	90.6	-	84.4	90.6	90.6	-	-
KKKJ4163	95.5	100	-	81.82	-	100	100	-	-

Table 3. Percentage of students who scored a minimum of 50 marks for specific courses for the mechanical engineering programme for semester 1 2011/2012

	PO MARKS								
CODE	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**
KKKF1111	-	-	-	-	-	-	100	-	-
KKKM1513	60.3	-	-	-	74.4	98.7	98.7	-	-
KKKM1914	98.4	98.4	98.4	-	98.4	-	-	-	-
KKKM2013	100	-	-	-	-	100	-	-	-
KKKM2314	97.1	-	-	-	95.7	98.6	98.6	-	-
KKKM2114	87.3	96.8	-	-	81	93.7	-	-	-
KKKM2513	95.6	100	-	-	-	82.6	-	-	-
KKKF3283	-	98.8	-	98.8	-	-	98.8	98.8	-
KKKJ3143	95.2	97.6	92.9	-	97.6	92.9	92.9	-	-
KKKJ3333	100	100	-	-	100	100	100	-	-
KKKL3004	91.7	85.0	-	-	96.7	-	85.0	-	-
KKKJ3933	81.8	100	100	-	81.8	-	100	-	-
KKKJ4353	95.2	96.8	-	-	96.8	96.8	-	-	-
KKKJ4953	96.6	100	100	-	-	-	100	100	100
KKKJ4013	100	100	100	100	100	100	100	100	-
KKKJ4573	83.3	88.9	-	-	94.4	-	-	-	-
KKKJ4553	77.8	77.8	-	-	77.8	-	-	-	-
KKKJ4364	100	93.8	100	-	-	100	-	-	-
KKKJ4143	100	100	100	100	100	100	-	-	94.4

PO assessments are correlated to the CO evaluation based on measurements that have been specified in the delivery and evaluation of the course at the beginning of each semester. Lecturers for courses provide a certain percentage of each element of evaluation (e.g., assignments, examinations, etc.) that contribute to the COs. Percentage weighting may be found in the teaching files for each semester. The percentage of students who obtained a minimum score of 50 marks is derived from the grading template and then transferred to the monitoring template.

This type of monitoring can provide an overview of each subject offered to ensure the quality of PO delivery. Tables 2 and 3 show the PO performance of individual courses offered by the mechanical engineering programme over two consecutive semesters. The listed courses were offered in the specified semesters. For almost all courses, 80% of students met the required standards by scoring a minimum of 50 marks for individual

PO. However, five subjects, KKKM1324, KKKM2324, KKKJ3124, KKKM1513, and KKKJ4553, failed to meet the departmental standards. The small marks on POs, was related to the average score grade achieved by the student. If the average marks were low, it also indicates a low POs marks. All the marks were depended with the course assessment and low average may because of a lot of factors such as the type of assessment of the course, level of question being asked, the attitude of the students, the successfully of course delivery and much more. The PO achievement results will be discussed during the meeting of the quality unit (UP3) each semester (six-month cycle) after grading is completed for the course. The department, through the UP3 committee, identifies the causes of low PO achievement and informs the respective lecturers so that corrective action could be taken. Every course subject need to report their POs and COs course achievement in the course file for the department and faculty record. They also need to discuss the reason behind their low POs and COs marks (if applicable) and the action taken to counter back the deficit or the improvement can be made in the future. Changes and improvements in the delivery and assessment methods for the course are undertaken as part of a continuous quality improvement process for the programme in JKMB.

For programme level monitoring, a measurement of each PO for every course can be conducted. However, selecting certain core courses that represent the measurement of a certain PO is more appropriate. The choice of courses is determined by the department based on the courses' importance in terms of contribution to a particular PO. For example, to represent PO1, the courses considered are the KM1344, KM2114, KJ3124, KJ3933, and KJ4953, whereas for PO9, KJ4703 and KJ4953 are considered. For each PO, at least two courses are selected to provide a cumulative measurement.

Figure 4 shows the average percentage of student achievement for each PO based on a particular subject or all subjects, excluding elective courses. PO is measured based on the CO's the relationship with and contribution to the PO (CO attainment directly measured for each course). From figure 4, it shows that all POs exceeded the target of 80%. PO1 recorded the lowest achievement at 86.9% for selected subjects and 90.1% for all all subjects.

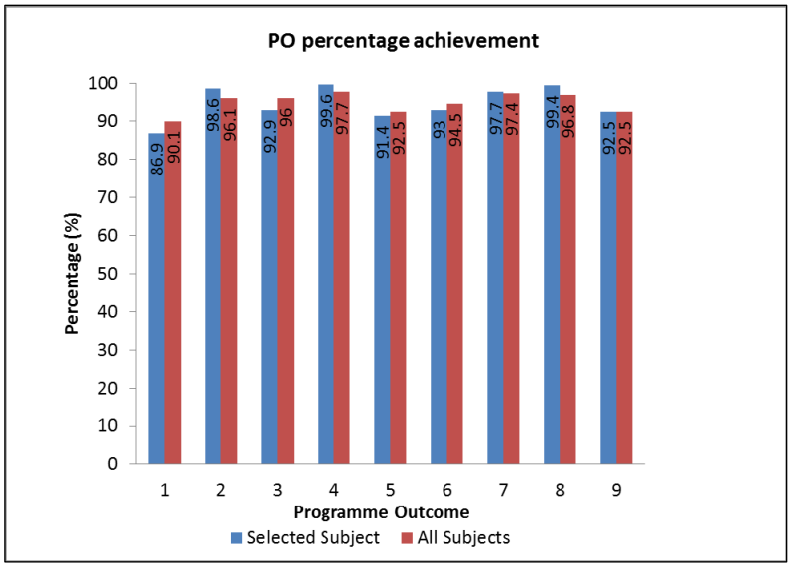


Figure 4. Percentage of student achievement for each PO (Achievement for 50 marks and above)

There are quite difficult to indicate student PO achievement beside the direct measurement from academic assessment and indirect measurement which is student perception. However, high student PO achievement can be demonstrated indirectly through the active participation of students in numerous national and international competitions such as the Perodua Eco-Challenge (2009, 2011, and 2012), Shell Eco-Marathon Asia (2010, 2011, and 2012), Proton Green Mobility Challenge 2012, and Malaysian Autodesk Design Competition (2010 and 2011).

4. Conclusion

All POs have generally scored over 80% which are satisfied for programme level monitoring. The results are based on the theoretical aspect (class lectures) and the practical aspect (exposure through participation in

competitions and association. However, for course level monitoring, a number of courses can further enhance their PO achievement. This comprehensive monitoring system ensures that each course's PO achievement is determined by the department. The department can identify the elements of underachievement and then inform concerned lecturers to take action for the purpose of continuous quality improvement, as intended for all EAC report documentations.

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